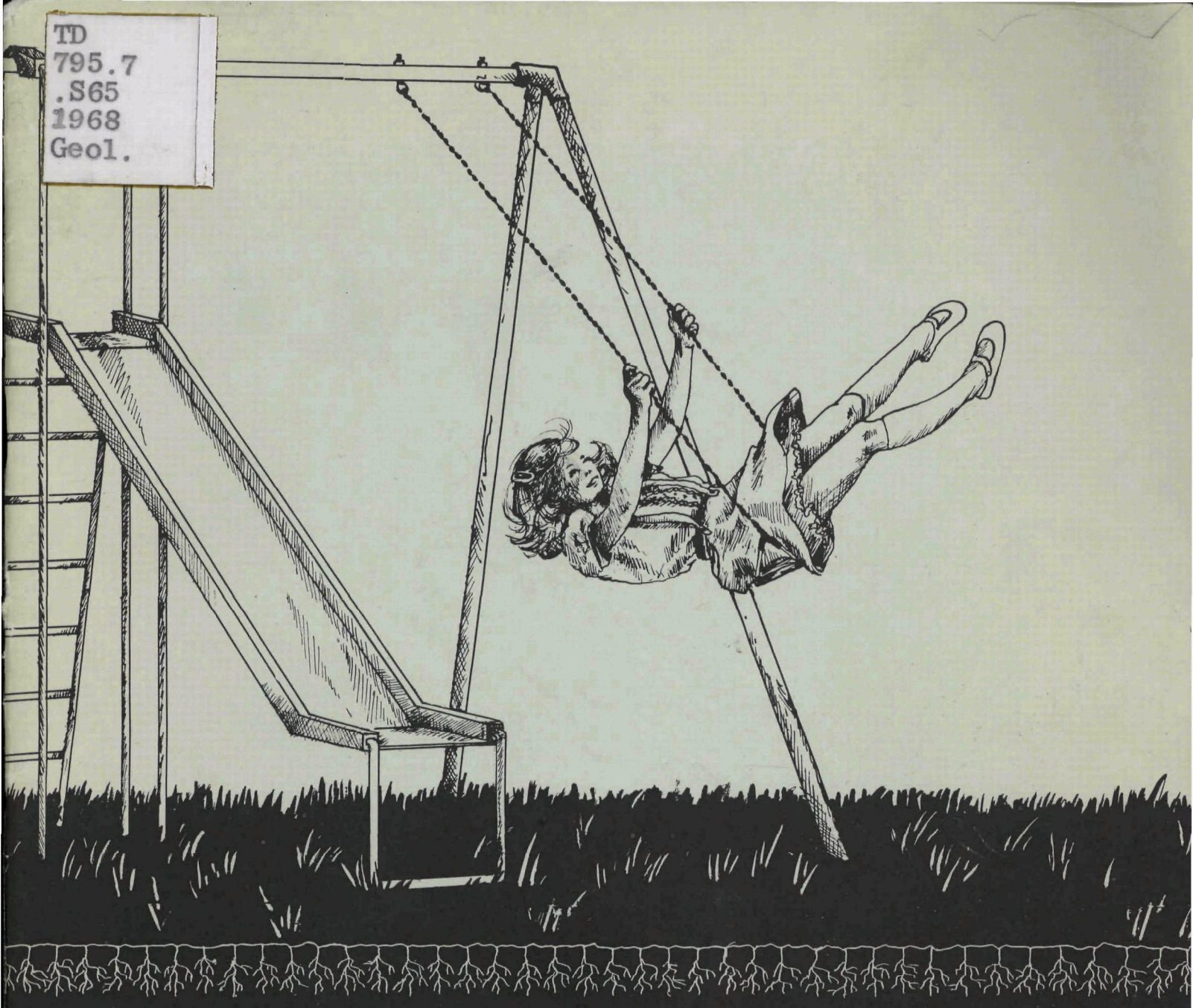

SANITARY LANDFILL FACTS

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Public Health Service
NATIONAL CENTER FOR URBAN AND INDUSTRIAL HEALTH
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FOREWORD

For many years our polluted environment has been the object of growing concern. Water and air pollution have received national attention and treatment for a decade, but solid waste disposal, which has been called the third pollution, entered the national limelight only during the past two years with the passage of the Solid Waste Disposal Act of 1965.

Public apathy toward the disposal of solid wastes is no longer commonplace. In many communities, the public is rejecting the traditional open burning dump. Citizens are recognizing the need for safe and sanitary management of solid wastes. Thus, the demand increases for properly engineered, effective, and economic solid waste disposal facilities.

SANITARY LANDFILL FACTS presents general information on the state-of-the-art of one basic, acceptable, and effective method of solid waste disposal--the sanitary landfill. This publication examines the planning, design, operation, and public health aspects of sanitary landfills. This information is offered as an aid to the growing number of people involved with planning and development in solid waste disposal management.

Richard D. Vaughan
Chief, Solid Wastes Program

CONTENTS

These photographs demonstrate how open dumps contribute to water and air pollution. Open dumps are also sources of food and harborage for insects, rodents, birds, and other wildlife that may act as disease carriers.

MISCONCEPTION

Upon hearing the term, 'sanitary landfill,' many of us immediately picture the traditional open, frequently burning, dump.

This misconception is quite natural because in many instances the term 'sanitary landfill' has been misused as the label for an open dump. The fact is, however, that a true sanitary landfill is not an open dump.

SANITARY LANDFILL FACTS

The sanitary landfill is defined by the American Society of Civil Engineers as: "A method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation, or at such more frequent intervals as may be necessary."[1]

Such a landfill is a well controlled and truly sanitary method of disposal of solid wastes upon land. It consists of four basic operations: (1) The solid wastes are deposited in a controlled manner in a prepared portion of the site; (2) the solid wastes are spread and compacted in thin layers; (3) the solid wastes are covered daily or more frequently, if necessary, with a layer of earth; (4) the cover material is compacted daily. The final result can be a golf course or playfield as suggested on the cover design of this booklet.

PLANNING A SANITARY LANDFILL

A sanitary landfill is an engineering project. When sound engineering principles are applied, the result will be a successful operation and in most cases will save money. Most operational problems can be prevented in the initial development stages. This is easier and more economical than correcting the defects once the operation has begun.

The first step toward the ultimate goal of establishing a sanitary landfill operation, of course, is the initial planning phase. The preliminary planning develops the basic groundwork for the actual engineering phases of site selection, design, and operation. Advanced planning should include consideration of: a competent designer; a public information program; a survey of solid waste practices and possible sites; the method of financing; the ultimate use of the completed site; and site zoning arrangements.

Competent Designer

Engineering knowledge and experience in sanitary landfill site selection, design, and operation are essential requirements of the individual or agency chosen to develop the sanitary landfill. If the planning or operating agency does not have this engineering experience and competence, every effort should be made to obtain the services of the best engineering consultant available. Although a sanitary landfill is considered the most inexpensive of the approved methods of disposal, it is a mistake to assume that a successful operation requires little skill or knowledge of design and operation. The selection of an engineer or consultant is a poor place to attempt to economize. The money spent for the services of a competent designer will be realized in a sanitary landfill operation which is successful and acceptable to the public.

Public Information Program

Unfortunately, many citizens associate impressions of open burning dumps

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with sanitary landfills. Usually the planning of a sanitary landfill meets with some public opposition unless the operating agency has conducted acceptable operations elsewhere.

Preliminary planning should include an active public information program to explain to the public what makes a sanitary landfill work well and what benefits can be expected. In many communities, public acceptance of a sanitary landfill site is the most important factor in deciding whether it will exist--or not. Moreover, it is very useful in gaining public support and most helpful to a designer to have the final use of the landfill area determined in advance. An architectural rendering or a model of the completed site, as a park, playground, golf course, or other planned use, is a good public relations tool. When opposition is exceptionally strong to the proposed sanitary landfill, it is well to consider the installation of a temporary pilot operation to illustrate a good sanitary landfill, while soliciting newspaper and TV support and possibly even hiring professional public relations services for the program. It is well to remember, however, that the public will soon discover any discrepancies between the public information program and actual operations. Operations must be exemplary in order to gain public support.

Other Considerations

The responsible officials in the preliminary planning phase must decide how the initial cost and the operating costs of the sanitary landfill will be financed. These officials should also investigate the amount and reliability of available data concerning the quantity and characteristics of the solid wastes to be handled. If sufficient and reliable data necessary for proper site selection and design are not available, arrangements should be made to survey the area generating solid wastes to procure the necessary information. If at all possible, the ultimate use of the completed landfill site should be decided during the initial planning stage. As stated previously, knowing the final use of the site will permit the designer to plan more effectively and will be useful for gaining public support for the project. In many instances, zoning restrictions have interfered with the development of an area for a sanitary landfill. Many legal problems can be avoided if preliminary planning includes arrangements for zoning potential areas for sanitary landfill operations and ultimate site use.

SELECTING A SITE

An important engineering step toward establishing an acceptable sanitary landfill operation is site selection. As with the preliminary planning phase, proper site selection can eliminate many future operational problems. Most of the many factors to be considered when selecting a sanitary landfill site will require technical know-how, a knowledge of equipment, and experience, and so it bears repeating that a well qualified individual or agency should be responsible for site selection.

Land Requirement

The land area--or more important the volume of space required--is primarily dependent upon the character and quantity of the solid wastes, the efficiency of compaction of the wastes, the depth of the fill, and the desired life of the landfill. Data on the quantity and character of residential, commercial, and industrial solid wastes to be landfilled are therefore necessary for estimating the space required. In estimating volume requirements, volume reduction of the solid wastes due to compaction must be considered. The desired life of the landfill

is another major factor in determining the total volume required.

The volume requirement for a sanitary landfill should be determined using the specific data and information available for each individual project. As a rough rule of thumb, however, about 7 acre-feet (11,293 yd^3) per 10,000 population per year is frequently used.

Zoning Restrictions

A survey conducted by the American Public Works Association in 1956 indicated that a high percentage of cities are restricted in the acquisition of disposal sites by their zoning ordinances.[2] Consequently, before a full-scale investigation of a potential site is undertaken, all zoning ordinances should be reviewed and cleared or changed to eliminate any legalities which could prevent or indefinitely hold up the use of a particular parcel of land for a sanitary landfill. Advance planning to zone the potential landfill site areas for sanitary landfill operation can circumvent many of these problems.

Accessibility

It is important to select a site that truck traffic can easily reach on highways or arterial streets. Sites requiring the trucks to travel through residential areas will normally draw many complaints, and such sites should be avoided.

The roads to the site should be of such width and construction to handle all sizes of trucks when fully loaded, during all weather conditions. Such problems as narrow bridges, low underpasses, and steep grades on the access routes should also be investigated. Since the site should be accessible at all times, it is desirable to have several access routes so that if one route is temporarily unusable the site can still be used.

Haul Distance

The haul distance is an important economic factor in selection of the sanitary landfill site. The economic distance to the site will vary from locality to locality depending upon capacity of collection vehicles, hauling time, and size and methods of the collection agency. The larger the quantity of refuse hauled per trip and the shorter the hauling time due to express roads, freeways, etc., the greater the distance the solid wastes can be hauled for the same cost.

Cover Material

The availability of cover material is another economic factor to consider when choosing the site, for the cost of hauling cover material to the site can be excessive. It is desirable, therefore, to select a site that has cover material available or close by to keep these costs at a minimum.

The field investigation of the potential site should include soil analysis to determine the suitability and the quantity of soil available for cover material. Soil with good workability and compaction characteristics is the most desirable cover material. Sandy loam is considered to be excellent since it contains about 50 to 60 percent sand and the remainder is clay and silt in equal amounts with good workability and compaction qualities.

Geology

The potential danger of ground and surface water pollution resulting from the landfill cannot be overlooked. Solid wastes ordinarily contain many contaminants and often infectious materials. These can produce serious health hazards or nuisances if permitted to enter water supplies. Site selection should include a geological investigation of the site, which can be run in conjunction with the

cover material field investigation, to determine the potential of either ground or surface water pollution. The ground water table must be located and information obtained on the historical high ground water level and on the general movement of the ground water.

The geological investigation should also examine the topography of the site itself and the surrounding area for potential flooding conditions of the site during heavy rains and snow melts. Flooding and surface water drainage can quickly erode the cover material and the refuse fill. Special attention should be given to low-lying sites that might be drainage basins for surrounding areas. Sites located near rivers, streams or lakes also deserve careful scrutiny. Generally, a landfill should not be located in a flood plain because of the water pollution hazard, and because such sites are unusable both during, and for a period following, flood conditions.

Climate

In some locations, climate conditions are important considerations in site selection and may even dictate the method of operation. In an extremely cold locality, a site requiring excavation of trenches and cover material may become a problem because of the frost during the winter months. However, a site requiring excavation operations can be used in a wintery locale if special operating procedures are planned in advance to cope with the expected problems; the trenches and cover material may be excavated during the summer months to carry the operation through the winter period.

In areas receiving considerable rainfall, a low-lying site may not be desirable because of flooding and continual muddy working conditions. In rainy areas, a site high in relation to the surrounding area, with good drainage features, is desirable.

In windy locales, a site surrounded by natural windbreaks will help to contain loose paper, thus reducing the amount of this material which may be blown off the site.

Fire Control Facilities

Although there is little chance of fire at a sanitary landfill when operated in accordance with good practices, a sanitary landfill site should be provided with suitable fire protection. Despite the fact that fires can usually be extinguished by smothering with a blanket of earth, all sites should have water available for fire control. Special consideration for fire control facilities should be given to sanitary landfills located relatively close to residential or commercial structures and in extremely dry areas where the fire could spread quickly and do extensive damage if not brought under control immediately.

DESIGNING A SANITARY LANDFILL

The design and operational steps during development of the sanitary landfill are not distinct phases. Basic knowledge and experience in the operational aspects of a sanitary landfill are necessary for the design phase. In essence, the design phase develops the plan of operation. It consists primarily of determining the operational plan and preparing the necessary detailed plans and specifications for construction and operation. Good plans and specifications are essential for estimating costs, bids for contracts, and for operational control and inspection.

Plans

Detailed plans should be prepared showing the existing topography and the designed contours of the completed land-

fill. As mentioned above, in the planning section, it is extremely helpful to the designer when designing the final ground elevations, if the use of the completed landfill has been previously determined. The plans should show the overall plan for landfilling, the drainage features, location of the cover material, and the wet weather operation site. The plans should also detail all construction features such as access roads, personnel and equipment facilities, scales, fencing, signs, waterlines and other utilities.

Specifications

The plans should be complemented with a set of specifications for construction and operation. Construction specifications cover the construction materials, workmanship, and equipment. The operating specifications should detail the method of operation including the weighing of the wastes, the cross sectioning of the site at definite time intervals, the thickness of cover material, the depth of lifts and cells, compaction, and wet weather operation procedures.

OPERATING A SANITARY LANDFILL

The importance of the appearance of the sanitary landfill during operation cannot be overly stressed. The operation is the only phase of the project that is seen by the public. Consequently, public acceptance of the entire project--the planning, design, and operation--will be based solely on the operation.

There are many factors involved in the operation of a sanitary landfill. A well operated sanitary landfill is the goal of the planner, designer, and operator and, therefore, each must have a thorough knowledge of all the factors to guide him in achieving this goal.

Supervision

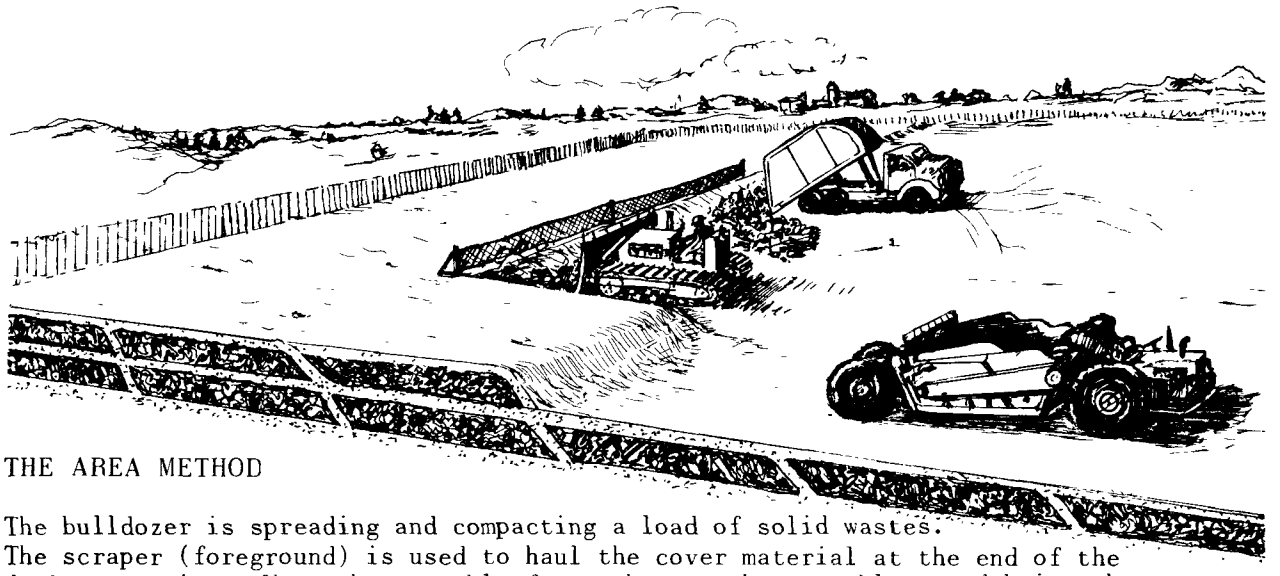
A clean, orderly, and economic operation requires constant and competent supervision. It is also important to employ only experienced or adequately trained personnel to operate a sanitary landfill.

Operating Records

For continuing evaluation and future planning, detailed records should be kept of the sanitary landfill operations. Records should be kept of the incoming material: the weights, the type, and the origin. Any deviation from the plan of operation should also be recorded. Topographic surveys of the landfill should be made regularly to determine the rate of space utilization. The incoming-material data and the topographic surveys can be used to determine the amount of material generated per capita, compaction, land use, operation efficiency, and to estimate the degree of decomposition and eventual settlement. Good cost-accounting records should be maintained, including the initial cost of the land and equipment, and the operating cost of the labor, equipment, equipment maintenance, depreciation, etc. These data are necessary for budgetary planning, for determining the cost rates for users, and for comparison with other operations, justifying expenditures, and estimating the efficiency of operation.

Directions

Sanitary landfills, particularly those open to the public, need directional signs and markers on nearby highways to help speed traffic movement. At the entrance to the site, a large legible sign should be posted to inform the public of the hours of operation, cost of disposal, and rules and regulations (such as, "only covered



THE AREA METHOD

The bulldozer is spreading and compacting a load of solid wastes. The scraper (foreground) is used to haul the cover material at the end of the day's operations. Note the portable fence that catches any blowing debris; these are used with any landfill method, whenever necessary.

trucks permitted"). At large sanitary landfill operations, signs should also be used on the site to direct the users to the unloading area.

On—site Roads

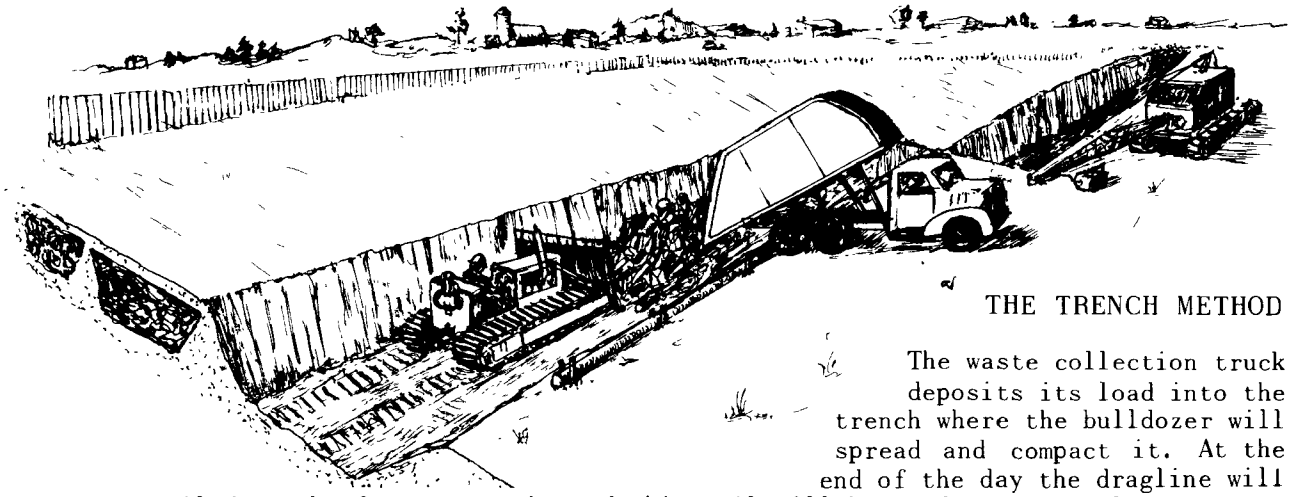
The on-site roads to the unloading area should be of all-weather construction and wide enough to permit easy two-way truck travel. Road grades should be designed for the largest fully loaded trucks to travel at a reasonable rate. It is particularly important at large sites that traffic in and out of the area should flow smoothly.

Methods

Sanitary landfilling consists of the basic operations of spreading, compacting, and covering. Over the years, two general methods of landfilling have evolved: the area method, and the trench method. Some schools of thought also mention a third, the slope, or ramp, method. In many operations, a slope, or ramp, is used in combination with the area or trench methods. For this reason, three methods will be described: area landfill, trench landfill, and the ramp, or slope, method.

In the area landfill, the solid wastes are placed on the land; a bulldozer or similar equipment spreads and compacts the wastes; then the wastes are covered with a layer of earth; and finally the earth cover is compacted. The area method is best suited for marshes, flat areas, or gently sloping land and is also used in quarries, ravines, valleys or where other suitable land depressions exist. Normally, the earth cover material is hauled in or obtained from adjacent areas.

In a trench landfill, a trench is cut in the ground and the solid wastes are placed in the trench. The solid wastes are then spread in thin layers, compacted, and covered with earth excavated from the trench. The trench method is best suited for flat or gently sloping land where the water table is not near the ground surface. The advantage is that normally the material excavated from the trench can be used for cover with a minimum of hauling. A disadvantage is that more than

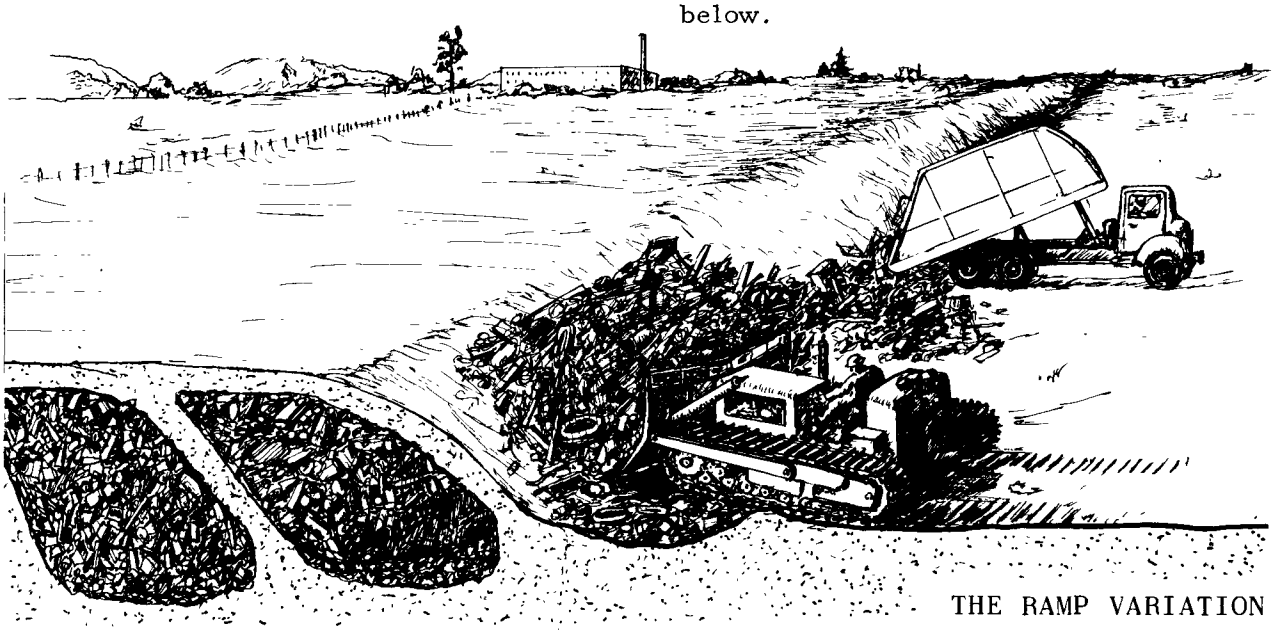


THE TRENCH METHOD

The waste collection truck deposits its load into the trench where the bulldozer will spread and compact it. At the end of the day the dragline will excavate soil from the future trench, and this soil will be used as the daily cover material. Trenches can also be excavated with a front-end loader, bulldozer, or scraper.

one piece of equipment may be necessary.

In the ramp or slope method (a variation of the area and trench landfills), the solid wastes are dumped on the side of an existing slope. After spreading the material in thin layers on the slope, the bulldozing equipment compacts it. The cover material, usually obtained just ahead of the working face, is spread on the ramp and compacted. As a method of landfilling, this variation is generally suited to all areas. Having the advantage of utilizing only one piece of equipment to perform all operations makes the ramp or slope method of landfill particularly applicable to smaller operations. The slope, or ramp, is commonly used in the area and trench landfill and is illustrated below.



THE RAMP VARIATION

The solid wastes are being spread and compacted on a slope. The daily cell may be covered with earth scraped from the base of the ramp. This variation is used with either the area or trench method.

Compaction

Solid wastes should be placed at the top or base of the working face, spread in thin layers about 2 feet thick, and compacted. If a slope, or ramp, is used, better compaction will normally result if the wastes are spread and compacted from the base upwards. The degree of compaction is dependent on the character of the solid wastes, the weight and type of compacting equipment, and the number of passes the equipment makes over the material. The actual density of the landfill can be determined from operating records and data. The degree of compaction is a useful tool to determine the rate of space usage, expected life of the landfill, and the overall efficiency of the operation.

Working Face

The size of the working face of the landfill operation is determined by the rate of unloading of the incoming vehicles. The working face should be as narrow as possible to minimize the exposed area, but not so small as to interfere with the unloading operations and the movement of landfill equipment. A minimum width of the working face should be approximately twice the width of the tractor to allow the tractor to move from side to side thus compacting the entire exposed surface.

Depth of Cells

Cell depth is the thickness of the solid wastes layer measured perpendicular to the working slope where the equipment travels. The depth of cells is determined largely by the size of the operation, the elevation desired of the completed fill, the depth of the trench or depression to be filled, and in some cases, the amount of cover material available. Eight feet is generally recommended as a maximum single cell depth because deeper cells usually result in fills that have excessive settlement and surface cracking. However, the cell depth of presently operated sanitary landfills varies from 2 feet to 15 feet or more.

Cover

The compacted solid wastes should be covered at the conclusion of each day's operation, or more frequently if necessary, with a minimum of 6 inches of compacted earth. Because of its workability and compaction characteristics, a sandy loam soil is the most desirable cover material. But if sandy loam is not available on the site, it may be necessary to adjust the covering procedures to the type of cover material available or to haul in more suitable cover material. The cover is necessary to prevent insect and rodent infestation, blowing paper, fires, the attraction of gulls, and the release of gas and odors.

For daily cover, a minimum of 6 inches of compacted sandy loam is recommended. For intermediate cover on lifts which will not have additional lifts placed on them within a year, a minimum of 12 inches of compacted sandy loam is recommended. A minimum of 2 feet of compacted sandy loam is recommended for the final cover. The final cover should be placed over the fill as soon as possible to help assure that wind and water erosion does not expose the wastes. Where trees will be planted on the completed fill, a depth of 3 or more feet of compacted earth has been found necessary.

Large Bulky Items

Large bulky items such as car bodies, refrigerators, water heaters, and tree stumps, can be handled routinely with other solid wastes at large landfills that use heavy equipment. At small landfills

STEPS IN OPERATING A SANITARY LANDFILL

Unloading Solid Wastes

Spreading and compacting of refuse followed by earth covering


CITY OF HAMILTON
DEPT. OF PUBLIC WORKS
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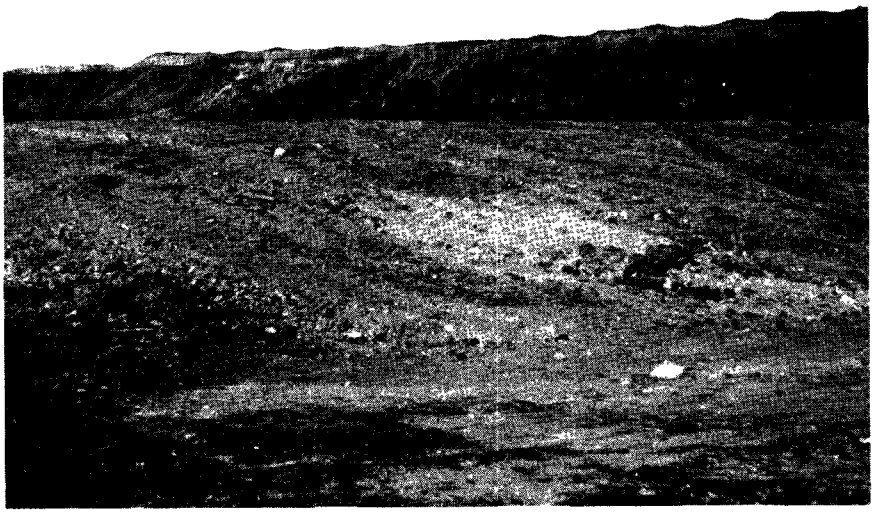
End of
the day



where light equipment is normally used, special provisions may be necessary to handle bulky items. A separate unloading area at the site or an alternate site, operated in a sanitary manner, should be utilized for the disposal of bulky items that cannot be handled routinely with the other solid wastes.

Blowing Paper

In a 1959 survey of sanitary landfill operations by the American Society of Civil Engineers, the operating problem most frequently reported was that of blowing paper.[3] The common method of controlling blowing paper is with a combination of permanent and portable fences. Unfortunately, under certain wind conditions the paper may blow up and over the fences, so that fences do not provide complete control. Prompt compaction and covering are also useful in controlling windblown paper. It is important, therefore, that the designer consider the prevailing wind direction when designing the operation.

Maintenance

Routine maintenance will be required to maintain a clean, orderly, and acceptable operation and site. It is important, particularly at public sanitary landfills, to cut the grass and weeds, pick up the scattered paper, maintain good access roads, control dust, and maintain clean and attractive employee and public facilities.

Drainage

To prevent ponding on the landfill surface with resultant excessive seepage into the landfill, drainage must be provided. This will prevent runoff water from eroding the cover material and exposing the wastes. Drainage must be provided both during the filling operation and for the completed landfill. Good drainage will usually require periodic regrading of the site, and the use of culverts or grassed waterways. It is recommended that the slope of the surface of the completed fill be a minimum of 1 percent. Since the landfill will undergo uneven settlement, it may be necessary to design the original slope for more than 1 percent to maintain a 1 percent slope after settlement. To prevent erosion, however, steep slopes should be avoided.

Winter Operations

Experience has shown that with good planning and proper operating techniques, a sanitary landfill can be operated throughout even the severe winters of North Dakota. Where the trench method of landfill is used, the trenches should be excavated before the cold weather season. It may be necessary to stockpile cover material and cover it with straw, leaves, or other material to prevent freezing. The material should be piled loosely with minimum compaction. All snow and ice should be removed from the trenches before use; it is good practice to use snow fences to protect the access roads. Also, a well-constructed, heated, tractor cab enables the operator to work efficiently during the cold weather.

Wet Weather Operation

Wet weather can seriously hamper the operations of a sanitary landfill by making the soil too soft, mucky, or slippery for equipment operation. Wet weather can also seriously interfere with trenching, covering, and general traffic flow to and from the working face. For these reasons, all-weather access roads and drainage should be built. In many cases, it is advantageous to stockpile such materials as concrete rubble, broken as-

phalt pavement, stone, etc., for use on the site roads during wet weather. This will minimize the cost of constructing and maintaining hard-surface roads to the unloading area. It is also desirable to provide a temporary wet weather landfill area adjacent to the all-weather road. Such sites are used only during the wet weather periods when the normal working area is not accessible.

Particular attention must be given to landfills when the trench method is being used. If pumping or good drainage is not provided, the trenches will fill with water, resulting in possible ground or surface water pollution and complete shut-down of the operation.

Salvage Operation

The American Society of Civil Engineers has stated that generally the most objectionable disposal sites from the standpoint of appearance are those where the salvage activity is the greatest. [1] To ensure clean and orderly sites and to prevent landfills from looking like open dumps, salvage operations should be prohibited at all sanitary landfill sites.

PUBLIC HEALTH AND NUISANCE ASPECTS

Vector Control

In a properly operated and maintained sanitary landfill, insects and rodents are not a problem. Well-compacted wastes and cover material are the most important factors in achieving vector control. Six inches of compacted earth cover is recommended for preventing the emergence of houseflies from the fill. Good compaction of the cover material also discourages rodents from burrowing through the cover material. Good housekeeping and daily covering of the solid wastes are musts for vector control.

Water Pollution

Under certain geological conditions, the burial of solid wastes is a real potential for chemical and bacteriological pollution of ground and surface water. Several investigations of the pollution of ground water from sanitary landfills have indicated that if a sanitary landfill is intermittently or continuously in contact with ground water, the ground water can become grossly polluted and unfit for domestic or irrigational use. Proper planning and site selection, however, combined with good engineering design and operation of the sanitary landfill can normally eliminate the possibility of either surface or ground water pollution. Some of the common preventative measures used are: (1) locating the site at a safe distance from streams, lakes, wells, and other water sources; (2) avoiding site location above the kind of subsurface stratification that will lead the leachate from the landfill to water sources, i.e., fractured limestone; (3) using an earth cover that is nearly impervious; (4) providing suitable drainage trenches to carry the surface water away from the site.

Air Pollution

Air pollution caused by smoke should not occur. No burning should be permitted at a properly operated sanitary landfill. If a fire does occur, it should be extinguished immediately.

Dust

Dust is a nuisance that may occur at a sanitary landfill operation in dry weather. Dust generated at the unloading area can be controlled by sprinkling the unloading area and the deposited refuse with water. Other dust control measures are the planting of grass or other vegetation on the finished fill and the application of

water, road oil, or calcium chloride to the access roads.

Odors

Odorous gases usually result from anaerobic digestion of putrescible material. The best control for odors is rapid and continuous coverage of solid wastes during the day and sealing surface cracks of the completed area of the landfill to prevent emissions of large concentrations of odorous gases.

Wildlife

Birds, particularly gulls, and other wildlife are common at open and burning dumps. There is little exposed food to attract wildlife at sanitary landfills. Most good sanitary landfill operations are free from these nuisances; however, there is no guarantee that all sanitary landfills will be completely free of wildlife. To keep the number of gulls and other wildlife to a minimum, the site should be kept clean, and the solid wastes should be covered promptly with earth.

Gas Production

Gas produced within a sanitary landfill consists chiefly of methane, nitrogen, carbon dioxide, hydrogen, and hydrogen sulfide. Methane gas is explosive and can be a hazard if accumulated in enclosed spaces. At landfills where methane and other gases are a problem, the gases should be dissipated into the atmosphere.

Hazardous Materials

Although it is not common practice, hazardous materials such as sewage solids, radioactive wastes, pathologic wastes, explosive materials, and chemicals can be disposed of at landfill sites under special conditions. The special provisions for handling and disposing of these materials will depend on local conditions. These materials may require individual handling and disposal in a special area separate from the main operating area. The necessary provisions should be considered during the design phase and, if appropriate, be included in the operational specifications.

EQUIPMENT

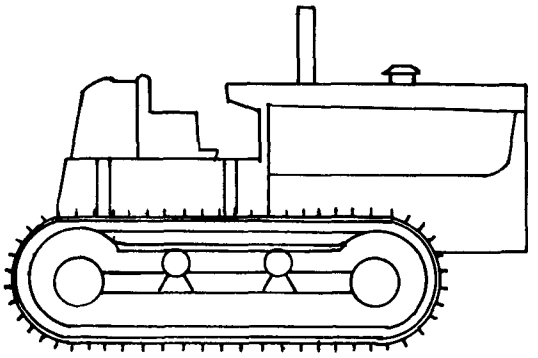
A wide variety of equipment is on the market today from which to select the proper type and size needed for an efficient operation. The size, the type, and the amount of equipment required at a sanitary landfill depend on the size and method of operation and to some degree on the experience and preference of the designer and equipment operators.

Type

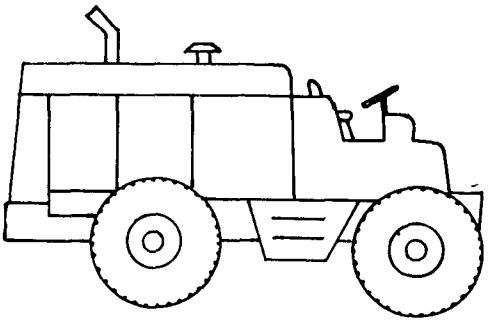
The most common equipment used on sanitary landfills is the crawler or rubber-tired tractor. The tractor can be used with a dozer blade, trash blade, or a front-end loader. A tractor is versatile and can normally perform all the operations: the spreading, compacting, covering, trenching, and even the hauling, of the cover material. The decision on whether to select a rubber-tire or a crawler-type tractor, and a dozer blade, trash blade, or front-end loader, must be based on the existing conditions at each individual site.

Other equipment used at sanitary landfills are scrapers, compactors, draglines, rippers, and graders. This type of equipment is normally found only at large sanitary landfills where specialized equipment increases the overall efficiency.

STANDARD LANDFILL EQUIPMENT

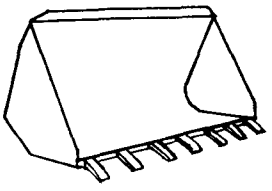


CRAWLER TRACTOR

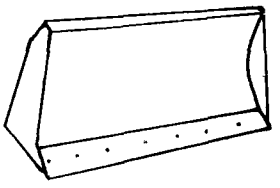


RUBBER–TIRED TRACTOR

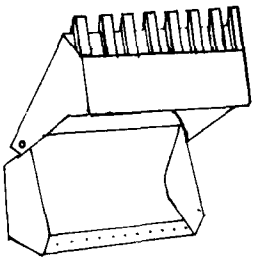
FRONT-END ACCESSORIES



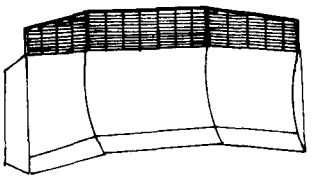
BUCKET



DOZER BLADE



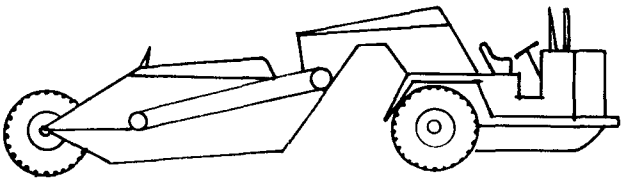
MULTIPURPOSE BUCKET

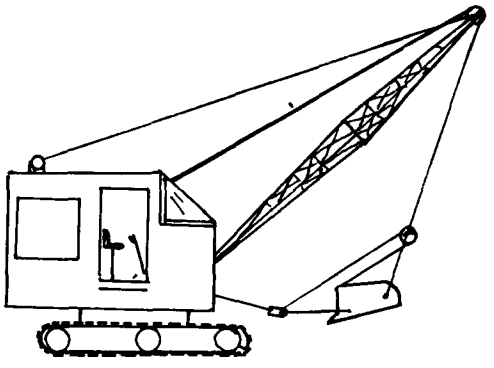


LANDFILL BLADE

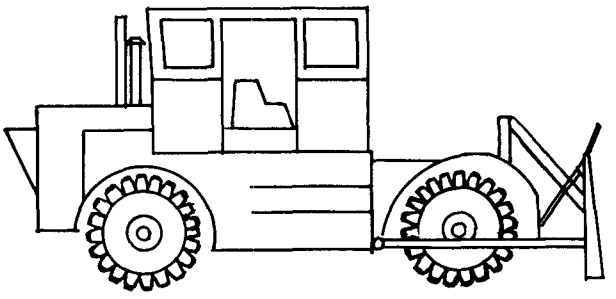
SPECIALIZED EQUIPMENT

SCRAPER





DRAGLINE



STEEL–WHEEL COMPACTOR

Size

The size of the equipment is dependent primarily on the size of the operation. Small sanitary landfills for communities of 15,000 people or less or sanitary landfills handling 40 tons of solid wastes per day or less can operate successfully with one tractor of the 5- to 15-ton range. Heavier equipment in the 15- to 30-ton range or larger can handle more refuse and achieve better compaction. Heavy equipment is recommended for sanitary landfill sites serving more than 15,000 people or handling more than 40 tons per day.

Amount

Sanitary landfills servicing 50,000 people or less or handling about 115 tons or less of solid wastes normally can manage well with one piece of equipment. At these small sites where only one piece of equipment is used, provisions must be made for standby equipment. It is preferable that a second piece of equipment be purchased and used for replacement during breakdown and routine maintenance periods of the regular equipment. Arrangements can normally be made, however, with another public agency or private concern for the use or rental of replacement equipment on short notice in case of a breakdown of the regular equipment.

At large sanitary landfills serving more than 100,000 people, or handling more than 260 tons of solid wastes per day, more than one piece of equipment will be required. At these sites, specialized equipment can be utilized to increase efficiency and minimize costs. Table 1 is offered as a general guide for the selection of the type, size, and amount of equipment for various sizes of sanitary landfills.

Table 1. AVERAGE EQUIPMENT REQUIREMENTS

Population	Daily tonnage	Equipment			Accessory*
		No.	Type	Size in lbs	
0 to 15,000	0 to 40	1	Tractor crawler or rubber-tired	10,000 to 30,000	Dozer blade Front-end loader (1 to 2 yd) Trash blade
15,000 to 50,000	40 to 130	1	Tractor crawler or rubber-tired	30,000 to 60,000	Dozer blade Front-end loader (2 to 4 yd) Bullclam Trash blade
		*	Scraper Dragline Water truck		
50,000 to 100,000	130 to 260	1 to 2	Tractor crawler or rubber-tired	30,000 or more	Dozer blade Front-end loader (2 to 5 yd) Bullclam Trash blade
		*	Scraper Dragline Water truck		
100,000 or more	260 or more	2 or more	Tractor crawler or rubber-tired	45,000 or more	Dozer blade Front-end loader Bullclam Trash blade
		*	Scraper Dragline Steel wheel compactor Road grader Water truck		

*Optional. Dependent on individual need.

FACILITIES

Small sanitary landfill operations will usually require only a small building for storing hand tools, equipment parts, etc., and a small shelter with sanitary facilities for the employees or a single building to serve both purposes.

Large sanitary landfill operations should have a maintenance and storage garage for the equipment, and an administrative-type building. If the scales are not adjacent to the administrative building, a scale house may also be needed. Sanitary facilities should be available for both employees and the public. In addition, it is recommended that locker rooms and showers be provided for the employees.

COSTS

The cost of a sanitary landfill consists of the initial investment for land, equipment, and construction features, and the operating costs.

Initial Investment

The magnitude of the initial investment depends on the size and sophistication of the landfill. A typical breakdown of the items that will normally make up the initial investment is as follows:

1. Land
2. Planning and designing
    a. Consultant
    b. Solid wastes survey
    c. Site investigation
    d. Design, plans, specifications
3. Construction
    a. Access roads
    b. Utilities--water, electricity, telephone, etc.
    c. Shelter and storage facilities
    d. Scales
    e. Fencing
    f. Miscellaneous--signs, site clearing
4. Equipment

Generally, the major portion of the initial investment will be for the purchase of the land and equipment. Often a sizeable part of the initial investment for land and equipment can be recovered through the development or use of the land and the salvage value of the equipment. If moneys are not available for the proposed investment, consideration should be made of leasing either the land or equipment or both to spread the cost over the operation.

Operation Cost

The operating cost of a sanitary landfill depends on the cost of labor and equipment, the method of operation, and the efficiency of the operation. The principal items that make up the operating cost are as follows:

1. Personnel--salaries and fringe benefits
2. Equipment
    a. Operating expenses--gas, oil, etc.
    b. Maintenance and repair

c. Rental, depreciation, or amortization

3. Cover material--material and haul costs

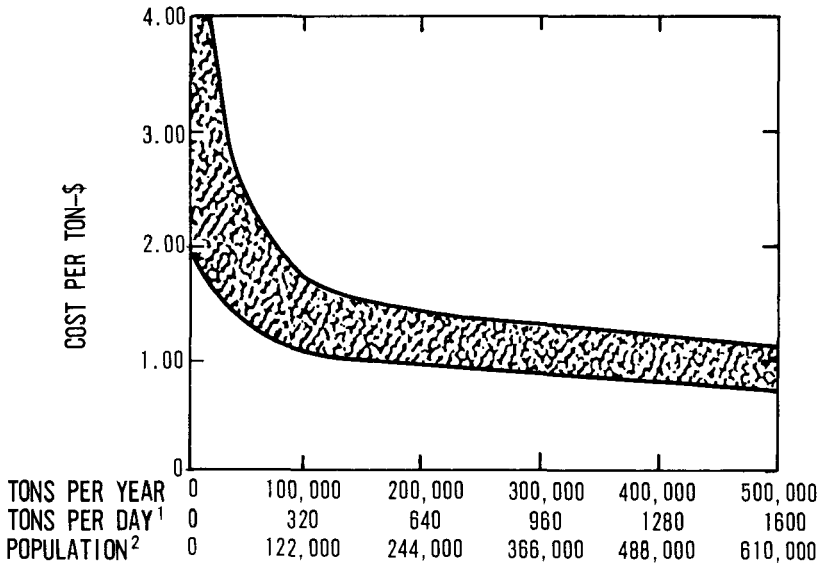
4. Administration and overhead

5. Miscellaneous--tools, utilities, insurance, maintenance to roads, fences, facilities, etc.

Labor wages will amount to about 40 to 50 percent of the total operating cost. Equipment will make up 30 to 40 percent; cover material, administration, overhead, and miscellaneous will amount to about 20 percent.

Figure 1 charts the operating costs per ton versus the amount of solid wastes handled in tons and the population equivalent. The unit operating cost of a small operation handling 50,000 tons per year or less varies from $1.25 to approximately $5.00 per ton. This wide range is primarily due to the low efficiency of the smaller operations which are normally operated on a part-time basis. Full-time personnel, full-time use of the equipment, specialized equipment, better management, and other factors that lead to high efficiency are possible at large sanitary landfill operations. The increased efficiency results in lower unit cost of disposal. The unit cost of a large landfill handling 50,000 tons or more per year will generally fall between $0.75 to $2.00 per ton.

To compare the true cost of sanitary landfilling with that of incineration or composting, it is essential that the costs and returns of the initial investments and the hauling costs be included along with the disposal costs. The hauling costs of a collection system that uses the sanitary landfill disposal method may be higher than the hauling costs of a system using



[1]Based on 6-day work week.

[2]Based on national average of 4.5 lbs per person per calendar day.

FIGURE 1. SANITARY LANDFILL OPERATING COSTS

incineration or composting, since sanitary landfills are generally located further from the waste-generating area than are incinerators or compost plants. In contrast to the possibility of higher hauling costs, a sanitary landfill may increase the value of a plot of unusable land by converting the site to a playground, golf course, park, etc., thereby obtaining a major investment cost advantage over incineration and composting.

COMPLETED SANITARY LANDFILL

Decomposition

Information available on the decomposition of buried material in a sanitary landfill indicates that it is extremely difficult to predict the time required for complete decomposition. Many items, particularly paper, have been found unchanged in landfills that had been completed for 15 to 25 years. The rate of decomposition is primarily dependent upon the moisture content and generally takes place at a very slow rate.

Decomposition of the wastes will result in the production of gases, principally methane, carbon dioxide, nitrogen, hydrogen, and hydrogen sulfide. The amount of gas produced during any time interval is dependent upon the rate of gas production; it will usually reach a peak within the first 2 years and then slowly taper off. Methane gas causes the most concern because of its explosive character. Precautions should be taken to prevent the gas from seeping into sewers or other structures located on or near the landfill.

Settlement

Settlement of the landfill is dependent on the depth of the fill, composition, compaction of the material, moisture content, and other factors. Studies have indicated that approximately 90 percent of of the total settlement will occur in the first 2 to 5 years. The final 10 percent will occur over a long-range period.

Underground Fires

Although underground fires rarely occur in a completed landfill, the possibility does exist. All underground fires should be dug up and extinguished. The cell construction feature of a sanitary landfill helps to confine and restrict the spread of the fire should one occur.

Maintenance

Completed landfills will generally require maintenance because of differential settlement. The maintenance will consist primarily of resloping the surface to maintain good drainage and filling in small depressions that result from uneven settlement.

Uses

Most completed landfill sites are used for recreational purposes such as parks, playgrounds, and golf courses. Completed landfills are also used for parking and storage areas and botanical gardens. Because of settling and gas problems, construction of buildings on completed landfills generally has been avoided; in several locations, however, one-story rambling-type buildings and airport runways for light aircraft have been constructed directly on sanitary landfills. In such cases, it is important for the designer to avoid concentrated foundation loading which can result in uneven settlement and cracking of the structure; and the designer must provide the means to allow the gas to dissipate to the atmosphere and not into the structure. However, multi-store buildings can be built over completed landfills, using steel and concrete pilings and special engineering design.

ADVANTAGES

The sanitary landfill has many advantages not common to other methods of disposal.

1. Where land is available, the sanitary landfill is usually the most economical method of solid waste disposal.
2. The initial investment is low compared to that of other disposal methods.
3. A sanitary landfill is a complete or final disposal method as compared to incineration and composting where residue, quenching water, unusable materials, etc., remain and require further disposal.
4. A sanitary landfill can be put into operation within a short period of time.
5. A sanitary landfill can receive all types of solid wastes, eliminating the necessity of separate collections.
6. A sanitary landfill is flexible; increased quantities of solid wastes can be disposed of with little additional personnel and equipment.
7. Submarginal land may be reclaimed for use as parking lots, playgrounds, golf courses, airports, etc.

DISADVANTAGES

1. In highly populated areas, suitable land may not be available within economical hauling distance.
2. If proper sanitary landfill standards are not adhered to, the operation may result in an open dump.
3. Location of sanitary landfills in residential areas can result in extreme public opposition.
4. A completed landfill will settle and require periodic maintenance.
5. Special design and construction must be utilized for buildings constructed on completed landfill because of the settlement factor.
6. Methane, an explosive gas, and the other gases produced from the decomposition of the wastes may become a hazard or nuisance problem and interfere with the use of the completed landfill.

PHS SANITARY LANDFILL PROJECTS

The Solid Waste Disposal Act of 1965 provided funds for surveys, demonstrations, studies, and investigations of new and improved technology of solid waste disposal. The Act authorized awards up to two-thirds the cost of the project and the awards are made by the Solid Wastes Program, National Center for Urban and Industrial Health, U.S. Public Health Service. A recent publication describing funded solid wastes demonstration projects, including those related to sanitary landfills, is available from the Solid Wastes Program.

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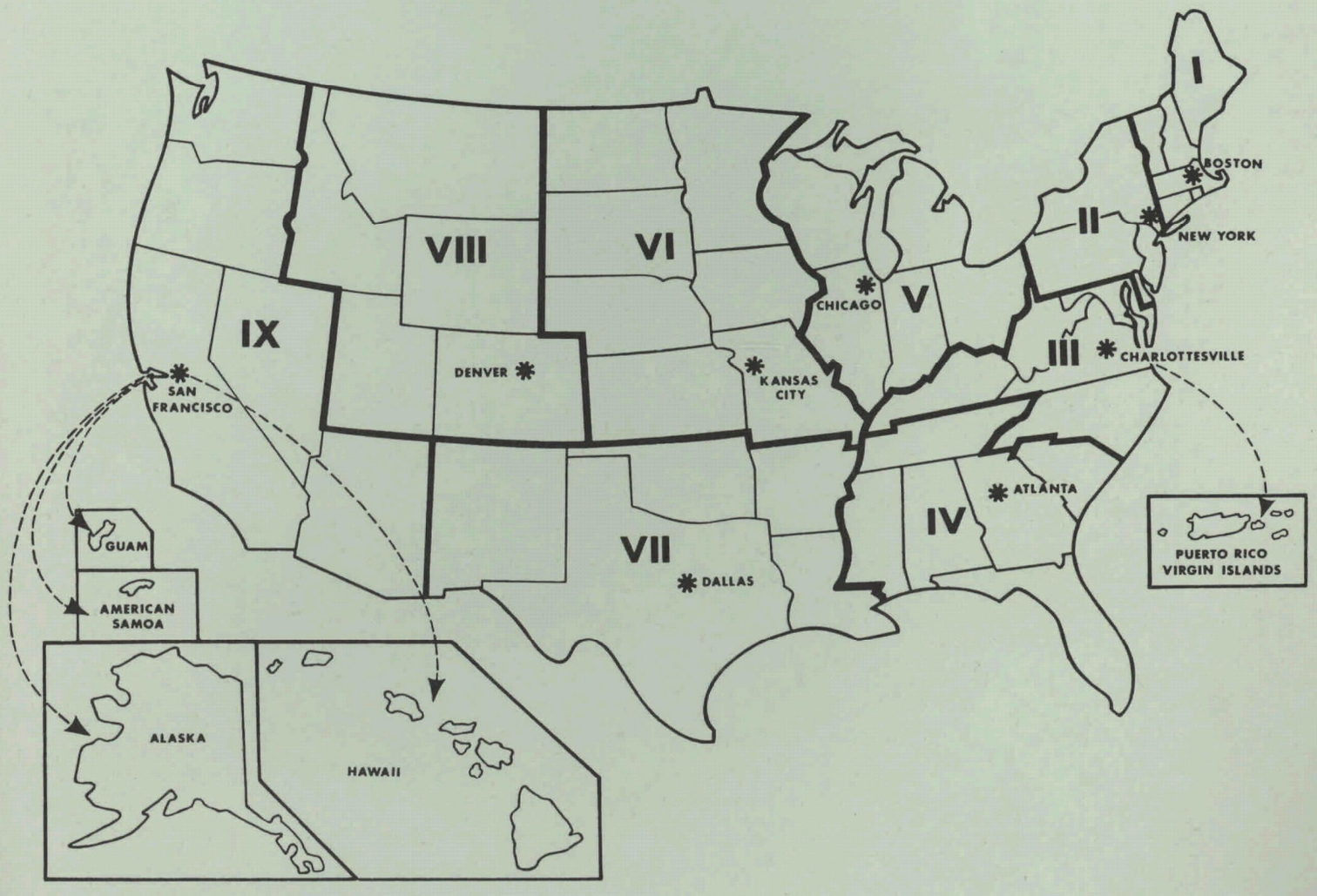

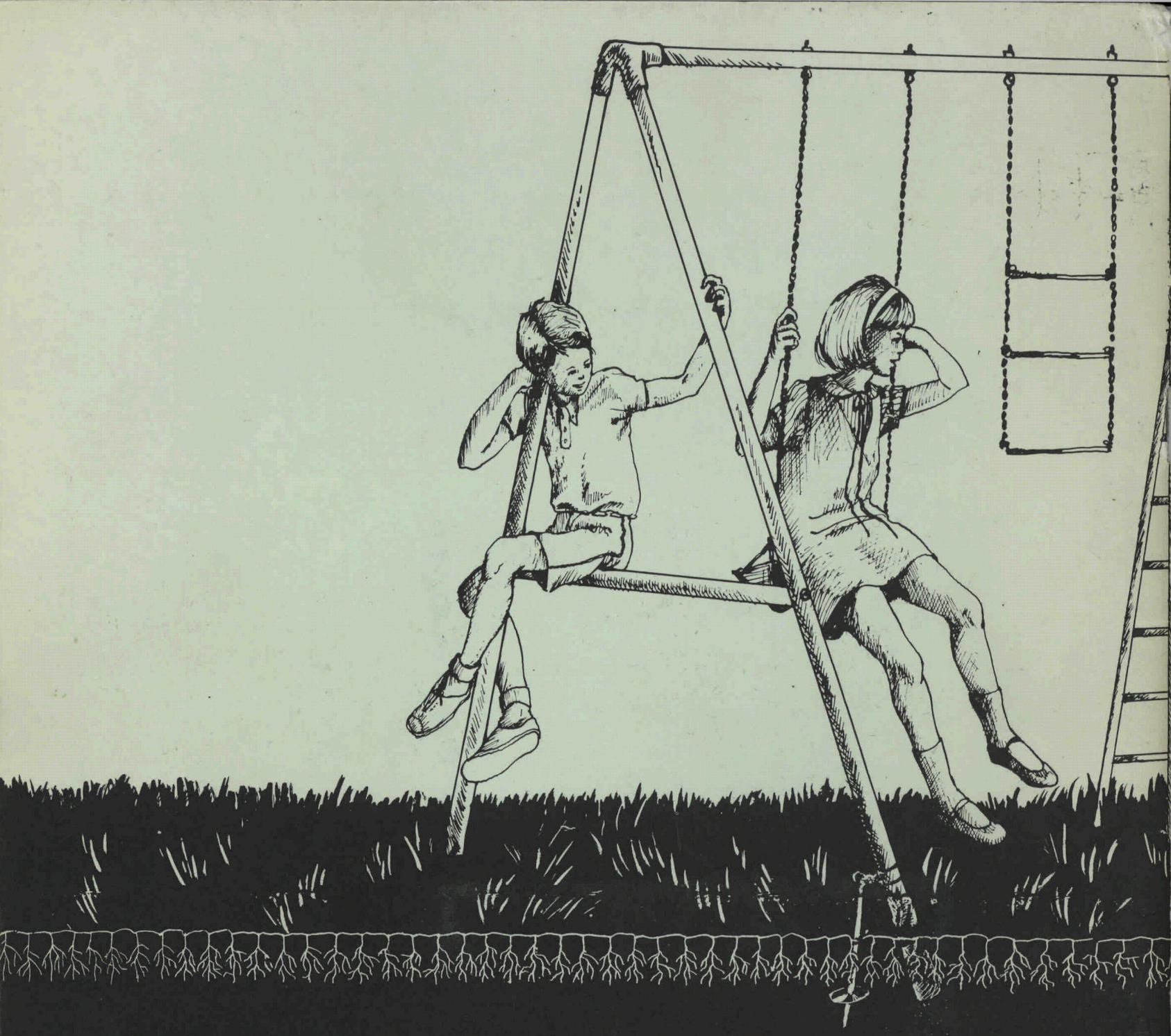

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